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ABSTRACT

The Space Telescope Science Institute (STScI), which supports the operation of the Hubble Space Telescope, is actively investigating and supporting innovative and experimental methods for improving science and math education content. The educational resources on the World Wide Web are derived from the latest data, scientific results, and advances in the supporting technology of the Hubble Mission. The resources and services offered are created through strategic partnerships between scientists, technical staff, educators, informal science institutions, and other key organizations. The inspirational nature of astronomical data lends itself well to multimedia applications and methods using new Internet technologies that cultivate exploration and discovery. Experiments conducted in bringing scientific content, human expertise and the technology together for the benefit of the public and the educational community are illuminating with regard to the barriers and cultural differences between the various participants. Topics discussed in this paper include: (1) astronomy and space science relevance to Web-based applications; (2) research tools and data migration; (3) STScI application, including strategic partnerships and teaming, presentation, and innovative processes; (4) other issues, including intellectual property, caching of resources, and training needs; and (5) samples of National Aeronautics and Space Administration (NASA)-funded Web-based programs and resources. (Author/DLS)

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Innovative Resources for Education and Public Information: Electronic Services, Data and Information from NASA's Hubble Space Telescope and Other NASA Missions

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Abstract: The Space Telescope Science Institute, which supports the operation of the Hubble Space Telescope, is actively investigating and supporting innovative and experimental methods for improving science and math education content. The educational resources on the Web are derived from the latest data, scientific results and the advances in the supporting technology of the Hubble Mission. The resources and services offered are created through strategic partnerships between scientists, technical staff, educators, informal science institutions and other key organizations. The inspirational nature of the astronomical data lends itself well to multi-media applications and methods using new Internet technologies that cultivate exploration and discovery. The experiments conducted in bringing the scientific content, the human expertise and the technology together for the benefit of the public and the educational community are illuminating with regard to the barriers and cultural differences between the various participants. Several examples of Internet based programs and activities are illustrative.

Introduction

Research scientists are increasingly aware that the public perception of the scientific process and the development of technology is frustratingly incomplete. Yet most people would admit that the functioning of our society depends upon developing an educational system that produces a literate workforce. Included in the skills that are needed in society are thinking, planning, and reasoning abilities along with agile navigation through information sources and manipulation of computer resources. Electronic communications and information technologies offer a new educational opportunities for individuals to experience and become adept at inquiry-based learning and discovery, both through self-guided means and through collaboration and coaching by educators, scientists and technically-oriented persons. Some aspect of such skills, from casual browsing of electronic materials to maneuvering through time critical electronic transactions, is relevant in every arena and industry.

Why Astronomy?

An area of scientific research that is fascinating to most people at intellectual as well as emotional levels is astronomy. Fortunately, observations of the cosmos coupled with the intricate analysis techniques which reveal the underlying physical nature of the objects studied lend themselves well to appealing multi-media applications. Contemplation of the technological advancements and instrumentation that astronomers deploy offers unlimited opportunities for creating enticing instructional tools. By examining the science data, information and expertise which is rapidly made available through on-line services to the scientific research community, one might expect that the underlying techniques and methods can be re-shaped and adapted to engage a broader audience such as the news media, the general public, businesses, educators, students and science and technology enthusiasts in the use of emerging technologies.

Astronomy and Space Science Relevance to Web Based Applications

Astronomical data is hard won in its highly competitive field - scientists acquire data through

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experiments conducted with high demand ground-based observatories, unique instruments on orbiting satellites and scientific probes launched into deep space. Due to the precious and competitive nature of the data acquired, and also the fact that each observational facility offers scientists access to a unique window into the physical universe, much astronomical material exists in on-line living archives offering access to information bases through relatively "standard" scientific formats or easily translatable formats. In addition, astronomy as a discipline has addressed the challenge of globally distributed information systems for nearly a decade. Accordingly, scientists have developed distributed computing infrastructure, search engines, location services, security mechanisms and conversion services to allow access through client-server and peer-to-peer technology to data which is distributed over a large number of host sites. The systems in use today have necessarily (by popular demand and intense fiscal pressure) migrated from the earlier proprietary systems to popular public access methods. Remarkably enough, a significant fraction of the astrophysics scientific community has agreed upon implementing Web based interfaces to the underlying, heterogeneous databases and archives scattered across the globe.

At the Space Telescope Science Institute, as for several other NASA missions, we strive to offer what were traditionally scientific resources to a wider audience who posses a large range in technical and scientific expertise. The obvious goal is to provide substance for educational curricula, but also to provide access to NASA resources for industry, the media, informal science centers (museums), and the general, international public, to name a few. The resources offered clearly can ignite interest in the particular science and discovery, but the data and information also can be woven together into imaginative tapestries to demonstrate emerging technologies. Specifically, astronomical content can be used for a plethora of educational purposes, for example to teach effective research techniques, mathematical concepts, scientific processes, historical perspectives, writing skills, appreciation of cultural differences and viewpoints. Beyond that, astronomical content can be used creatively to demonstrate technological methods: search engine functions, documentation techniques, graphical interfaces, interactive services, real-time collaborative services, security systems, database functions, distributed computing environments, etc. that can be mapped, by analogy, to other disciplines, especially those with less engaging content or information that cannot be exposed in a public forum.

The migration of resources and data from the arena of discipline experts to a more general clientele creates many challenges. In a distributed system created by and for the domain expert (e.g., scientists) the information to be accessed must be made much more locatable and understandable for general users with heterogeneous backgrounds. Material is useful in education if it can be located quickly through simple browse products (text, thumbnails, short clips) cleverly crafted as entry points to the more complete tiered structure of resources. Once found, resources must clearly be relevant to the user's purpose. A greater challenge has been to construct the browse products, demonstration materials and the core content itself in an engaging presentation which cultivates *new* uses, value added products, and further exploration into the Web. While the domain expert may be fairly unhappy with cumbersome interfaces, in fact, *experts often are strongly motivated to use awkward access methods if the content is pertinent to their needs*. However, domain experts, similar to most other users, are typically rebellious against using multiple interfaces or several disparate and complex software constructs to obtain necessary information.

Research Tools and Data - Migration

Motivated to broaden usage of science data to non-specialist users, we hoped that the relatively mature infrastructure ("middleware") built for providing distributed access to NASA data, analysis software, and ancillary information for scientists (e.g., the Astrophysics Data System [ADS] http://wwwads.harvard.edu/ or the Hubble Space Telescope Archive http://www.stsci.edu/) could be migrated transparently to the wider audience. However, *this was not the case*. The initial intent was to provide a simple Web based wrapper to the already existing scientific interfaces because it was speculated that fairly light weight Web services could be tailored easily for different clientele. In practice, however, we have found this is not trivial. First, access into the full set of scientific materials is hopelessly complex for the non-specialist, even when driven through a simple interface. A deeper technical difficulty arises from initial lack of "state" in Web services, so that it was not possible to retain many of the sophisticated distributed computing attributes of the original astronomical data systems in use. Therefore subsets of NASA data systems are available through the Web, but unfortunately now

without the backbone of middleware which once allowed scientists or anyone else to have "the universe on their desktop". An example of one of the sub-systems may be found through the "catalog service" at the ADS URL given above. Currently, several NASA projects are conducting experiments to grapple with these problems where one of the key goals is to provide ready access to resources without enormous and costly expenditures on infrastructure, interfaces and other re-design which would tax the severely diminishing resources in the missions.

Space Telescope Science Institute (STScI) Specific Application

The Office of Public Outreach (OPO) at STScI is responsible for disseminating scientific results, telescope and satellite information and other materials to all sectors of the public including educators. The other divisions at STScI concentrate on interaction with the science community and support the planning, scheduling, data acquisition, analysis and publication of results within the scientific research domain. To provide information in diverse ways to a broad audience, we are convinced that *direct involvement of the user in the design of services is critical*. In our experience with information technology industry, there is much lip-service given to such a strategy, but in fact, "representative users" are often allowed to be little more than temporary critics. User involvement *in the design* means that content relevant to a specific constituency is derived collaboratively through compromises and balance. *Knowledge of this approach frequently tempts the software engineer or scientist, "who knows better", to disengage from the process before it starts*. Therefore, managing collaborative projects is a challenging proposition and must include appropriate brokers to engage and mesh the expertise of the various participants productively. *Also, the research community must work conscientiously to demonstrate access to information infrastructure is actually useful, rather than acclaiming it so*. Therefore, OPO and other NASA supported programs have teamed educators and science museum personnel with scientists to provide engaging content that easily demonstrates the relevance of HST and other flight program materials to the public. Teachers, in particular, can then work cooperatively to appeal to school, local and state officials to obtain network access within their classrooms and computer laboratories. Another significant driver in working to develop an Internet savvy clientele is that dissemination of hard copy and other collateral material is expensive for any organization, especially since much of this material is originally generated in electronic form! It is far more effective to disseminate appropriate materials electronically, allowing users to pick and choose what materials they wish to obtain rather than providing large packets of collateral only a fraction of which will be used.

Strategic Partnerships and Teaming Are Critical: Cutting edge data and information from scientific investigations *should* naturally cascade through university graduate and undergraduate courseware to the K-12 community. At STScI, a research institution, close association with universities and community colleges starts to address this need. OPO/STScI support also is directed to the news media, to journalists providing public information, to science writers and to the science museum community. The initial hurdle is to educate those constituencies in the use of electronic information technology, and further to integrate news material into thematic packages which also contain materials appropriate to informal science and educational settings. *Organizing scientific data and resources along thematic lines is not trival* - archives and other information are often configured for particular flight missions, research objectives, or a specific scientific or technical clientele. Accordingly, the wide variety of types of users that OPO/STScI must support has offered the opportunity to experiment with a number of approaches for providing services. One of the meaningful (if not self evident) results of working in partnership with the users in the initial stages of specification of Web resources, is that we affirm that *access to human expertise, personal experience, face-to-face interactions of developers, information brokers, and users, and initial period of building of rapport is essential, no matter how engaging or astonishing the technology to be used is. The building of trust and credibility is important if expensive multi-media resources are to be any more than of fleeting interest to users.*

Presentation - Effect on Understanding: Another arena of investigation is to understand how the use of interactive technology (such as Java applets, Shockwave, etc.) conveys information, and what information is added, lost or altered when such technology is not used. This is often relevant for the competitive world of the news media and public information, where the "angle", that is, the specific presentation of content, can impact the effectiveness of a news story or journal article. In education, such issues are even more relevant. It is not always evident what presentation is the most effective. For

example, in the presentation of the new map of the surface of Pluto - assembled through analysis and modeling of a series of "snapshot" high resolution HST images - the whirling planetary globe is an attention grabber, and clearly by using it, the TV journalist has the edge over a newspaper writer. In education, the snapshot images, the Mercador projection, and the globe all represent the same information, but also convey information on how a mosaic of images becomes a map, how globes are projected into flat surfaces, how scientific modeling relates to actual data, and finally how HST is used to study rotating objects. These concepts can be described at length textual form, but rarely developing quick insight for the viewer/reader.

Innovative Processes: Another issue which is not well understood yet is: how important is novelty for multi-media in education? Certainly, engaging presentation is a time honored tactic to grab the learner's attention, but educators can ill afford to compete with the game industry to retain student interest. What are important are not only services that are innovative in their own right, but rather what *imaginative education processes* are built on interactive tools. For example, the recent "Live from Hubble" experiment involved a suite of on-line journals, chat sessions, interactive consultations with scientists, and rapid download of planetary images from HST, which were all inventive resources on their own. However, the combination intertwined into the overall program gave students and teachers a bond to STScI and to each other in a collaborative learning environment that was sustainable over several months. This would not have been achieved through use of any single tool, no matter how ingenious.

Other Issues

Clearly there is a plethora of educational and social issues surrounding Web use. One problematic area for educators, which directly impacts the work conducted at STScI is intellectual property rights and copyrights. While it is true that the rules of fair use usually state that employment of NASA materials for educational or non-profit purposes can be permitted or licensed, there remains a broad spectrum of interpretation of the law. The ambiguity is troublesome for educators and content providers who intend to exploit the Web for effective dissemination and access to resources, but have no intention to reap huge profits from the information accessed. Other organizations would be well advised to follow the lead of NASA missions in carrying an explicit statement that allows use and reproduction for education, in addition to their copyright notices. This is a great motivational factor for educators. OPO/STScI permits use of Web resources for education and research and pro-actively encourages widespread utilization of the dramatic imagery from HST (c.f. the copyright notice at the STScI web site: http://www.stsci.edu/).

OPO/STScI recognizes that our customers enjoy a large range in connectivity, technical expertise and desktop computer power. We have begun our own study regarding the resources which may need to be cached either at remote sites or downloaded frequently by users who need rapid recurrent access to some materials. For example, STScI serves a significant number of international users, so building mirror sites is a logical step, but some sites have capacity for only a limited amount of the high demand resources. Furthermore, we are studying which materials teachers prefer to download in advance of scheduled classroom activities so that classroom access is relatively rapid. Clearly, caching of information will be a relevant topic for some time to come in situations where distributed systems serve a full range of connectivity including global markets.

The experimentation conducted within the astronomical community in partnership with science museums, teachers, students, universities, community colleges and libraries is primarily for the benefit of teachers, students, and informal science learners. However, the programs offer a rich suite of lessons learned on how to approach different clientele in a cost effective way, which amazingly are repeated time and time again by other research institutions and the industry. Research institutions and university departments cannot expend precious research resources to create a plethora of types of packaging, wrappers, services, and other ancillary materials to reach the public. In the case of STScI, the public's thirst for materials quickly overwhelms the available support structure. Technical training and access to infrastructure are still problematic for the general user, and *it is not clear to the scientific research community how receptive the public will be to newly marketed products and services without sufficient training and education.* It is evident that as the ranks of the research community shrink as fiscal support dwindles, only small, focused education programs will be feasible.

A Few Samples of NASA Funded Web Based Programs and Resources

Program	*Description and Link*
Space Telescope Science Institute (STScI)	Public Information, News, Education Resources, Classroom Modules - http://www.stsci.edu/public.html
Science Information Infrastructure	Educational Resources, Lesson Plans, Classroom Activities. Partnership - Researchers, Science Museums, Industry, Educators - http://www.cea.berkeley.edu/Education/SII/
Remote Sensing Public Access Center (RSPAC)	Publicly Accessible Data and Resources, Links to NASA supported Programs in Space Science and Earth Science, Supports NASA Information Infrastructure and Technology Program (IITA) - http://www.rspac.ivv.nasa.gov/
Other IITA Programs	Aeronautics, Digital Library Initiatives, K-12 Programs - http://rsd.gsfc.nasa.gov/rsd/iita/IITAproj.html

Summary

Using astronomical research as a context, and drawing upon almost a decade of experience in distributed computing techniques, the astrophysics community is well placed to experiment with a variety of techniques, methods and technologies for Web use. Interaction with industry would be beneficial for both communities. OPO/STScI serves a wide variety of users (news media, scientists, general public, teachers, administrators, students, parents, etc.) who require access to resources at different levels of complexity, on different timescales and through several types of interfaces. The advantage of astronomical content is that most individuals find it motivational so that experiments addressing some key issues relevant to information technology and Web use in a variety of situations find welcome participants. The creation of resources can be accomplished successfully through strategic partnerships with knowledgeable brokers, educators, science museum personnel and others. In addition, innovative resources are useful only if they are interwoven into imaginative and engaging processes that have learning as the primary end product.

We continually re-learn and reinforce the idea that strategic partnerships that involve suitable information brokers result in the best migration of science and technology to the public. These brokers must not only be knowledgeable about domain specific content and possible new uses, but also must be sensitive to the "cultural" background of the participants. For example the scientific and technical fields are highly competitive, often introspective and rarely easy to interface with whereas the non-expert demands ease of use, a tiered structure of information and engaging materials. The NASA mission is expressly to foster research, experimentation, innovation and unusual or risky technology development. NASA funded programs cannot and should not be aimed at duplicating efforts initiated by other federal agencies or industry, and in particular can support but not drive systemic education reform.

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